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Evaluation of cerebral venous return with internal jugular vein blood flow in gynecological laparoscopic surgery

Cerebral venous return in gynecological laparoscopic surgery

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Abstract
Aim: The steep Trendelenburg position is frequently used in laparoscopy to improve the surgical image. However, this positioning combined with pneumoperitoneum raises concerns especially in relation to cerebral hemodynamic physiology.
In this study, we aimed to evaluate the effects of pneumoperitoneum and steep Trendelenburg position, applied in laparoscopic gynecological surgeries on cerebral venous return, with changes in internal jugular vein (IJV) blood flow.
Material and Methods: Twenty patients who underwent laparoscopic gynecological surgery under general anesthesia were included in the study. IJV cross-sectional area (CSA) and Doppler flow velocity were measured with an ultrasonography device at the end of inspiration. IJV blood flow (ml/min) was calculated with the formula of cross-sectional area (cm^2) × Doppler flow velocity (cm/sec) × 60. The first measurement was performed in the supine position immediately after endotracheal intubation. The second measurement was performed 1 hour after applying pneumoperitoneum and 25° Trendelenburg position.
Results: In the steep Trendelenburg position, there was a significant increase in right and left IJV CSA ($p = 0.001$; $p = 0.038$) and blood flow ($p = 0.005$; $p = 0.039$), while no significant difference was observed in Doppler flow rate.
In the supine position, the right IJV CSA and blood flow were significantly greater than the left IJV CSA and blood flow ($p = 0.015$ and $p = 0.017$).
Discussion: The steep Trendelenburg position and pneumoperitoneum in laparoscopic gynecological surgeries caused an increase in bilateral IJV blood flow to raise cerebral venous drainage.

Keywords
Cerebrovascular Circulation, Jugular Vein, Laparoscopy, Pneumoperitoneum, Trendelenburg Position

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Introduction

Laparoscopic surgery has advantages over open surgery such as minimal tissue damage, earlier recovery and lower complication rates. Laparoscopy is increasingly applied in the diagnosis and treatment of gynecological diseases [1,2]. The Trendelenburg position (TP) is routinely used in laparoscopy to increase the surgeon's field of view. The steep Trendelenburg position is defined as a 25°-45° downward head tilt of a patient lying in the supine position [2,3]. This position provides an ideal field of view in surgeries using laparoscopic and robotic techniques [3,4] but also causes changes in the physiology of tissues and organs and some complications [4,5]. Some of these complications are increased cardiac output and central venous pressure (CVP), decreased lung compliance, and increased peak and plateau pressure [6]. The steep Trendelenburg position also affects cerebral venous drainage. These changes, which disrupt tissue physiology are exacerbated by hypercapnia due to carbon dioxide (CO2) absorption after pneumoperitoneum administration [7].

More than three-quarters of the cerebral venous flow in the supine position is supplied by IJVs [8]. The diameter and blood flow of IJVs, which are responsible for most of the cerebral venous drainage, vary depending on TP [9-13]. In awake, spontaneously breathing patients, the IJV blood flow does not change at the 10° TP position [11] but increases at the 12° TP position [13] . These results are valid for awake spontaneously breathing patients and may be different in patients administering mechanical ventilation under general anesthesia. Since positive pressure ventilation and pneumoperitoneum can influence cerebral venous flow dynamics. Therefore, this study aimed to assess the effects of pneumoperitoneum and steep Trendelenburg position (25°) on IJV blood flow in patients undergoing laparoscopic gynecological surgery.

Material and Methods

Study design and study population

This clinical, prospective, and observational study was approved by the Ethics Committee of our institution on 13.11.2019 (approval number 2019–310). Also, this study was registered at www.clinicaltrials.gov (NCT04922060). Patients aged 18-65 years with ASA I-II and planned for elective laparoscopic gynecological surgery were included in the study. Written informed consent was obtained from patients who agreed to participate in the study. Patients who had head and neck surgery and had a history of cerebrovascular disease were excluded from the study.

Anesthesia management and surgical position

Standard monitoring consisting of electrocardiography (ECG), pulse oximetry and non-invasive blood pressure measurement was applied to the patients. Induction of anesthesia endotracheal intubation was performed 2 minutes after 5-7 mg/kg thiopental, 1 mcg/kg fentanyl and 0.6 mg/kg rocuronium administration. Anesthesia was provided with O2/air mixture (FiO_2 40%), 1 MAC sevoflurane and 0.1-0.5 mcg/kg/min remifentanil infusion. In mechanical ventilator volume control mode, tidal volume was set at 6-8 ml/kg and positive end-expirium pressure (PEEP) at 5 cm H_2O.

The abdominal cavity was inflated with CO_2 until a pressure of 12-15 mm Hg was achieved and trocars were inserted. After the patients were placed in the 25° TP position, the PEEP was increased to 7 cm H_2O. The respiratory rate was adjusted to achieve an end-tidal CO_2 between 4.0 and 4.7 kPa. All surgical procedures were performed in the 25° TP position.

Measurements

Patients' demographic data (age, height, weight, body mass index), anesthesia and surgical data were recorded. IJV measurements were performed using a Doppler-enabled ultrasonography (US) device (Mindray Bio-medical Electronics Co., Shenzhen, China) at a frequency of 6-14 MHz. The measurements were performed by an anesthesiologist with five years of experience. The linear probe was placed at the point where a horizontal line drawn at the level of the cricoid cartilage (C6) cuts the IJV. The cross-sectional area and Doppler velocity of the IJV were measured at the end of inspiration without pressing too much on the US probe (Figures 1 and 2). The IJV cross-sectional area was obtained using an ultrasound caliper to trace the circumference of the vessel manually. The first measurement was performed in the supine position immediately after endotracheal intubation. The second measurement was performed 1 hour after the pneumoperitoneum was applied and the Trendelenburg position (25°) was reached.

Flow (ml/min) was calculated using the following formula: cross-sectional area (cm^2) × Doppler flow rate (cm/sec) × 60.

Sample size calculation

The sample size calculation is based on our pilot study with six patients. Accordingly, 19 subjects were required for an α value of 0.05 and power of 85% when the mean difference and standard deviation (SD) of pneumoperitoneum and TP and IJV flow were set to 257 and 67 ml/min, respectively. Twenty patients were included in our study, considering possible data deficiencies.

Statistical analysis

Data were analyzed using the SPSS.20.0 program. The conformity of continuous variables to normal distribution was evaluated with the Kolmogrov-Smirov test and Shapiro-Wilk test. Paired t-test was used to compare IJV CSA, Doppler velocity and flow measurements between supine and Steep Trendelenburg positions. Results with a p-value of 0.05 were considered statistically significant.

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

Twenty patients were included in the study. Their average age was 48 (8) years, their average height was 158.9 (5.4) cm, their average weight was 77.9 (16.7) kg, and their average body mass index (BMI) was 30.94 kg/m2 (6.9) (Table 1).

The right IJV was found to be 70% larger, while the left IJV was larger in only 30 %. The right IJV CSA in the supine position was significantly larger than the left IJV CSA (p = 0.015). In the supine position, the blood flow was greater in the right IJV than in the left IJV (p = 0.017) (Table 2).

The significant difference between right IJV and left IJV CSA in the supine position was not observed under the Steep Trendelenburg position and pneumoperitoneum (Table 2).

The significant difference between right IJV and left IJV blood flow in the supine position was not observed under the Steep Trendelenburg position and pneumoperitoneum (Table 2).

There was a significant increase in right IJV and left IJV CSA (p = 0.001; p = 0.038) under the Steep Trendelenburg position and pneumoperitoneum (Tables 3). The combination of the steep Trendelenburg position (25°) and pneumoperitoneum increases the right IJV CSA by 37%, while left IJV CSA by 49 %.

There was a significant increase in right IJV and left IJV blood flow (p = 0.005; p = 0.039) under the steep Trendelenburg position and pneumoperitoneum (Tables 3). The combination of the steep Trendelenburg position (25°) and pneumoperitoneum increases right IJV blood flow by 54% while left IJV by 90% without changing the Doppler velocity.

Table 1. Demographic data

	Mean (SD)
Age, year	48.65 (8.17)
Weight, kg	77.9 (6.72)
Height, cm	158.95 (5.47)
BMI, kg/m²	30.94 (6.9)
Anesthesia time, min	145.24 (15.32)
Operation time, min	130.43 (12.16)

Values are presented as mean±SD, mean (range)

BMI: Body mass index

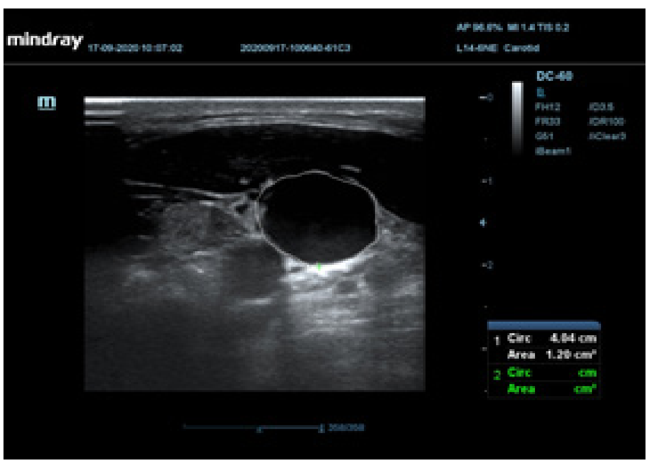

Figure 1. Measurement of Internal Jugular Vein Cross-Sectional Area.

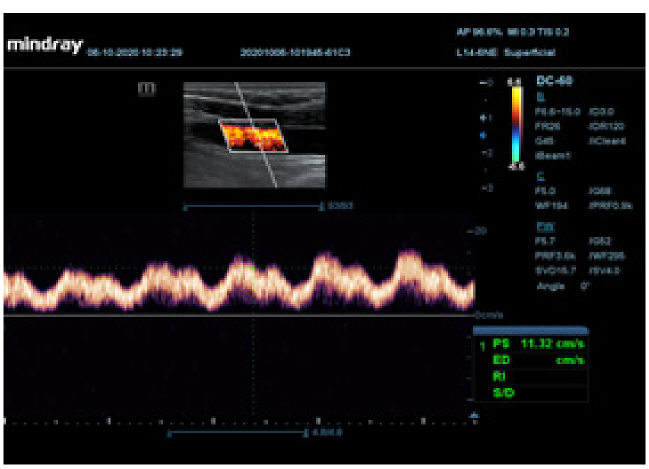

Figure 2. Measurement of Internal Jugular Vein Doppler Velocity.

Table 2. Comparisons of Right IJV's with Left IJV's measurements in the supine position and Trendelenburg position.

		Right IJV	Left IJV	p
Supine	Cross sectional area; cm²	1.90 (0.80)	1.43 (0.57)	0.015
	Doppler velocity; cm.s-1	10.56 (4.82)	8.70 (3.58)	0.159
	Flow; ml.min-1	1103.46 (494.17)	704.19 (312.60)	0.017
Trendelenburg	Cross sectional area; cm²	2.60 (1.04)	2.14 (1.42)	0.239
	Doppler velocity; cm.s-1	11.64 (5.30)	10.48 (4.12)	0.259
	Flow; ml.min-1	1705.99 (855.35)	1339.46 (1325.46)	0.316

Values are presented as mean±SD, mean (range); p< 0.05 was considered statistically significant; IJV: Internal Jugular Vein

Table 3. Comparison of position-dependent measurements in the Right and Left IJV.

		Supine	Trendelenburg	p
Right IJV	Cross-sectional area; cm²	1.90 (0.80)	2.60 (1.04)	0,001
	Doppler velocity; cm.s-1	10.56 (4.82)	11.64 (5.30)	0.393
	Flow; ml.min-1	1103.46 (494.17)	1705.99 (855.35)	0.005
Left IJV	Cross-sectional area; cm²	1.43 (0.57)	2.14 (1.42)	0.038
	Doppler velocity; cm.s-1	8.70 (3.58)	10.48 (4.12)	0.118
	Flow; ml.min-1	704.19 (312.60)	1339.46 (1325.46)	0.039

Values are presented as mean±SD, mean (range); p< 0.05 was considered statistically significant; IJV: Internal Jugular Vein

Discussion

This study has shown that the combination of the steep Trendelenburg position (25°) and pneumoperitoneum increases right IJV CSA by 37% while left IJV CSA by 49 % and right IJV blood flow by 54%, while left IJV by 90% without changing the Doppler velocity.

The steep Trendelenburg position optimizes the surgeon's field of view in laparoscopic surgeries. However, since there are still concerns that the pneumoperitoneum and steep Trendelenburg position, which are necessary for laparoscopic procedures, disrupt the physiology of tissues and organs, new studies are being conducted on this subject. In fact, the majority of patients undergoing laparoscopic surgery tolerate the combination of the steep Trendelenburg position and pneumoperitoneum. On the other hand, we cannot ignore the fact that the combination of steep Trendelenburg position and pneumoperitoneum is associated with some risks, especially in terms of intracranial pressure and brain perfusion [14] . The reason for this is thought to be the increase in arterial pressure and CVP in the steep Trendelenburg position, resulting in impaired venous drainage and increased hydrostatic pressure in the cerebral vascular system. Also, increased CO_2 in the systemic circulation due to pneumoperitoneum may increase cerebral blood flow by inducing cerebral vasodilation. The combination of these opposing effects makes it difficult to predict the final effect on cerebral blood flow [15]. Studies have attempted to determine this effect by methods such as invasive arterial pressure, central venous pressure, optic nerve sheath diameter, IJV valve ultrasonography, transcranial Doppler imaging of the middle cerebral artery, and cerebral tissue oxygen saturation [14-16]. None of these studies evaluated cerebral hemodynamics with IJV blood flow. The difference of our study is to obtain information about cerebral hemodynamics by evaluating IJV blood flow with Doppler ultrasonography, which is easier and cheaper to apply compared to the methods mentioned above.

In our study, the right IJV was found to be 70% larger, while the left IJV was larger in only 30 %. In a study on 91 cadavers, which is consistent with the results of our research, the right IJV was found to be 81.3% larger, while the left IJV was larger in only 11.0 % [17]. In a study that performed computer tomography (CT) scans of 313 patients and examined the relationship between internal jugular vein shape and various chronic diseases, it was shown that the right IJV has a larger cross-sectional area than the left IJV [18].

Studies to date have shown that TP increases the cross-sectional area of the IJV [9-12]. However, the majority of these studies did not evaluate the left IJV [10]. In our study, both IJVs were differently assessed, and it was found that the CSA of both IJVs increased in Trendelenburg position. The increase in the CSA of the IJV indicates compliance of the venous system. The increase in intracranial pressure that occurs in the Trendelenburg position is regulated by the enlargement of the high-compliance IJVs [13].

In our study, Doppler velocity in bilateral IJV did not change in TP. Contrary to our study, other studies showed that Doppler velocity in TP is significantly reduced compared to the supine position [11]. Although there are many reports in the literature about IJV Doppler velocity in TP, their results may contradict each other. This is because various factors, such as the procedure, duration, location of the measured vein, and the angle of the table, may lead to different interpretations [13,19]. In one study, the measurements by two researchers evaluating IJV CSA and Doppler velocity showed a strong correlation in terms of CSA but a poor correlation in terms of velocity. The reason for this is stated as the high probability of error in the measurements, since the dynamic velocity measurements are user-dependent [20]. In our study, three repeated measurements were made for velocity to minimize errors and the average of these measurements was used.

Our study, similar to the literature, has shown that IJV blood flow increases significantly in TP. IJVs are the main route of cerebral venous drainage in the supine position and continue this dominant role in TP. This increase in the blood flow of IJVs in TP shows the shift in the venous path in response to postural change [13]. Other studies show that the blood flow of IJVs decreases after 4.5 hours at 6° and 12° TP [21]. According to these results, the duration of the position may be an important factor in TP's role in cerebral venous drainage.

Another result of our study is the difference between right and left IJV blood flow in the supine position. Consistent with our research, in a study by Chung et al., blood flow in the right IJV was larger than in the left IJV [22]. This may be because the CSA of the right IJV is wider than the CSA of the left IJV. Studies have found increased intracranial pressure (ICP) in the Trendelenburg position [23,24]. However, despite an increase in ICP, focal or global neurologic deficits were not reported in the steep Trendelenburg position and pneumoperitoneum. Regional brain oxygenation and changes in optic nerve sheath diameter were investigated in near-infrared spectrometry to support this result. The fact that even the combination of steep Trendelenburg position and pneumoperitoneum is generally well tolerated by patients has been attributed to autoregulation that regulates cerebral blood flow. The increase in IJV blood flow, which is one of the results of our study and shown in patients in whom the steep Trendelenburg position and pneumoperitoneum were applied together, may be a component of the cerebral autoregulation mechanism that compensates for the increase in ICP.

There are several limitations in our study. Cerebral venous flow is complex because of affected by various physiological factors such as vertebral vein flow, cerebral arterial flow and cerebral perfusion pressure. Evaluating all these parameters together with the IJV in our study could have been more enlightening. Also, it is practically not possible to evaluate the vertebral veins with ultrasonography. Since the IJV is responsible for the vast majority of cerebral venous drainage, we used IJV flow as a surrogate marker for total cerebral venous flow.

Conclusion

Bilateral IJV blood flow increased to raise cerebral venous drainage in patients undergoing laparoscopic surgery in the steep Trendelenburg position.

Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest
The authors declare no conflict of interest.

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